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NASA Technical Memorandum 104454

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Prepared for the
26th Intersociety Energy Conversion Engineering Conference
cosponsored by the ANS, SAE, ACS, AIAA, ASME, IEEE, and AIChE
Boston, Massachusetts, August 4-9, 1991

NASA

FIBER-OPTIC SENSORS FOR AEROSPACE ELECTRICAL MEASUREMENTS: AN UPDATE

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ABSTRACT

Fiber-optic sensors are being developed for electrical current, voltage, and power measurements in aerospace applications. These sensors are presently designed to cover ac frequencies from 60 Hz to 20 kHz. The current sensor, based on the Faraday effect in optical fiber, is in advanced development after some initial testing. Concentration is on packaging methods and ways to maintain consistent sensitivity with changes in temperature. The voltage sensor, utilizing the Pockels effect in a crystal, has excelled in temperature tests. This paper reports on the development of these sensors. It also relates the technology used in the sensors, the results of evaluation, improvements now in progress, and the future direction of the work.

1. INTRODUCTION

Fiber-optic sensors that measure electrical current, voltage, and power have many advantages over conventional sensors. They are relatively immune to EMI, have wide bandwidth, low mass, and excellent isolation. They also will not fail during over-voltages or current-surges that would normally damage a conventional sensor.

Fiber-optic sensors developed for aerospace applications are designed to be broadband and accurate for ac frequencies as low as 60 Hz and as high as 20 kHz. This will allow use in 400 Hz aircraft systems, future 20 kHz spacecraft systems (such as electro-mechanical actuators or Advanced Launch Systems), and 60 Hz terrestrial systems. They are also designed to be stable over broad temperature ranges (-65°C to +125°C).

A prototype fiber-optic current sensor has undergone significant testing and has operated successfully at high vibration levels.[1] A second-generation device is in preparation. The advanced development of this sensor will concentrate on packaging methods to improve the temperature stability.

A prototype optical voltage sensor has been constructed and tested. The sensor has excelled in the temperature tests. Presently the voltage sensor is being modified to reduce sensitivity to vibration.

In this paper we will report the progress made on the development of aerospace current and voltage sensors which use fiber-optic and optical sensing heads. We will describe the technology used in the sensors, the results of evaluation, improvements now in progress, and the future direction of the work.

2. ELECTRICAL CURRENT SENSOR

Technology

Figure 1 is a schematic diagram of the electrical current sensor. The sensor uses the Faraday effect in an annealed coil of single-mode optical fiber through which the current carrying conductor passes.[2] The Faraday effect is a rotation of the plane of polarization of light as is propagates through a material in the direction of a magnetic field. The rotation of the plane of polarization is proportional to the current flowing through the conductor. Multiple turns of fiber increase the sensitivity of the sensor.

A polarization maintaining (PM) fiber transports linearly polarized light from the laser diode source to the sensing coil. Another PM fiber transports the light exiting the sensing coil to a polarizing beam-splitter and sensing photo-diodes. These optical elements convert the rotation of the polarization state into a change in transmittance so that a direct measure of the current in the conductor can be made.

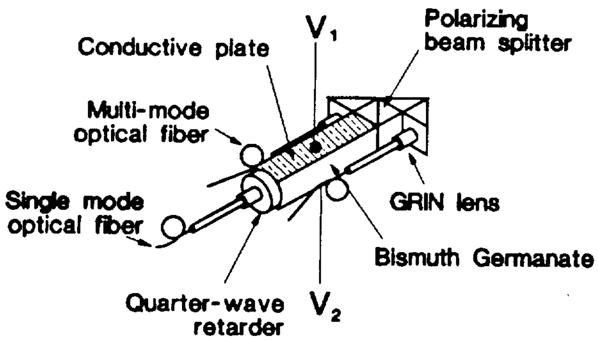

Figure 3 Diagram of the Fiber-Optic Voltage Sensor.

nents are held together with UV-curing glue. An early version of the voltage sensor used two optical fibers to deliver and return light. The noise floor was excessive because of the low light throughput. The latest version employs three fibers (one for input to the sensor head and two for return) and achieves a 10-fold decrease in the noise floor to an acceptable 0.5 to 0.7 V/√MHz.

Evaluation

The voltage sensor has undergone 30 temperature cycles over the range -65°C to +125 °C, and its temperature compensated output, as shown in Figure 4, falls within ± 1.3% over the temperature range of -70 °C to +130 °C. Output is about 1.2 mV rms per 1 V rms applied to the input.

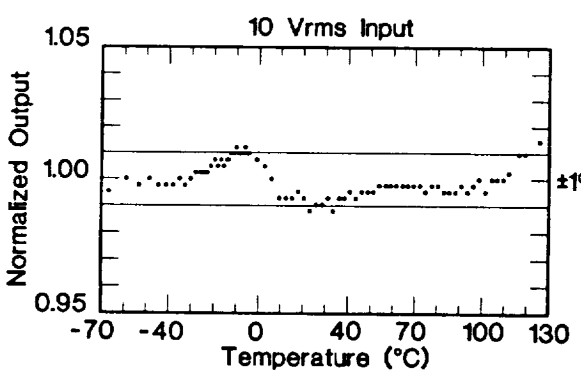

Figure 4 Output of the Voltage Sensor after 30 Temperature Cycles.

With the second version of the voltage sensor it was discovered that movement of the fibers which connect the sensing head to the electronics package caused excessive noise. It is believed that this problem is due to modal noise in the multi-mode fiber used for light input to the sensing head. To remedy the problem NIST is presently redesigning the voltage sensor to use a single-mode optical fiber for input. After the voltage sensor is rebuilt, it will be submitted to vibration tests very much like those described previously for the current sensor.

4. RELATED WORK IN OTHER ORGANIZATIONS

The US Navy has been supporting similar work at NIST Boulder on fiber-optic current sensors for shipboard applications. The Navy sensor has a different configuration called the vertically annealed design (VAD) seen in Figure 5. In this design, the plane of the sensing coil was turned roughly perpendicular to the direction of the PM input/output fibers. To date, this design has been used successfully over the required 0°C to +65°C range. Operation at lower temperatures has not been as successful, probably because of greater stresses placed on the fiber.

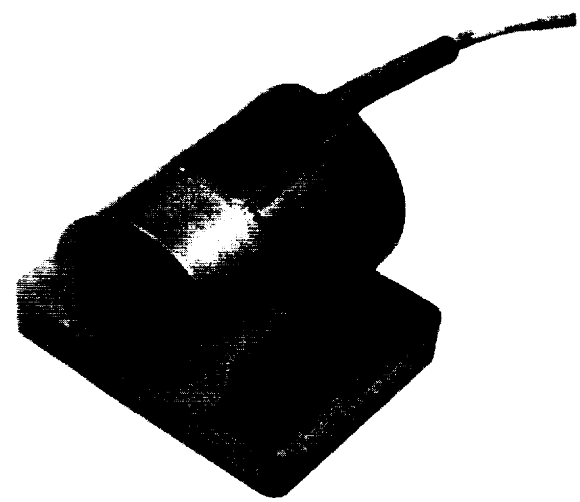

Figure 5 Fiber-Optic Current Sensor Using the Vertically Annealed Design (VAD).

Through a cooperative research and development agreement with NIST, a private U.S. corporation will soon be producing fiber-optic current sensors. Prototypes have been shown to prospective customers, and commercially available units will be offered in early 1992.

5. FUTURE WORK

In the near term, NIST will finish building a second-

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-104454		

4. Title and Subtitle
Fiber-Optic Sensors for Aerospace Electrical Measurements: An Update

5. Report Date

6. Performing Organization Code

7. Author(s)
R.L. Patterson, A.H. Rose, D. Tang, and G.W. Day

8. Performing Organization Report No.
E-6295

10. Work Unit No.
590-13-41

9. Performing Organization Name and Address
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

13. Type of Report and Period Covered
Technical Memorandum

14. Sponsoring Agency Code

15. Supplementary Notes
Prepared for the 26th Intersociety Energy Conversion Engineering Conference cosponsored by ANS, SAE, ACS, AIAA, ASME, IEEE, and AIChE, Boston, Massachusetts, August 4-9, 1991. R.L. Patterson, NASA Lewis Research Center; A.H. Rose, D. Tang, and G.W. Day, National Institute of Standards and Technology, Boulder, Colorado 80303. Responsible person, R.L. Patterson, (216) 433-8166.

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17. Key Words (Suggested by Author(s))
Sensors
Optical fibers

18. Distribution Statement
Unclassified - Unlimited
Subject Category 35

19. Security Classif. (of the report)	20. Security Classif. (of this page)	21. No. of pages	22. Price*
Unclassified	Unclassified	6	A02

NASA FORM 1626 OCT 86

*For sale by the National Technical Information Service, Springfield, Virginia 22161

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